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REVIEW ARTICLE

MODELLING OF HILLSIDES AND LOWLANDS SOILS FERTILITY DETERIORATION IN THE URBAN COMMUNE OF N'ZÉRÉKORÉ, REPUBLIC OF GUINEA, CASE OF NAKOYAKPALA DISTRICT

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ABSTRACT

The objective of this study is to examine the deterioration of the fertility of hillside and lowland soils in the Nakoyakpala district, in the urban commune of Nzérékoré, Republic of Guinea. The methods used are documentary research, systematic random survey and physicochemical parameters analysis using photometry**.** The results reveal that 65% of farmers practice parallel crop, 60% of them use chemical inputs and 80% dump waste into ditches, lowlands and waterways. Thus the lowland soils are more humid with a rate of 46.1%, the nitrate content (NO_3^-) in the lowlands varies between 25mg/l and 20mg/l, while on the hillsides is between 15mg/l and 45mg/l. Ammonium (NH_4^+) is higher in the hillsides with 3.5 mg/l than the lowlands with 3 mg/l. The pH varies between 4 and 4.5.In view of results from surveys and physicochemical analyzes, it is clearly established the deterioration of the soil is mainly due to bad crops practices. To illustrate the soil fertility degradation, physicochemical parameters of Nakoyakpala district lowland and Hillside soils is compare to the same parameters recommended standadrs for fertile lowland and hillside soils. The results showed pH, Humidity, density and ammonium of lowland and hillside soils of Nakoyakpala are well below compared to the recommended standards. However in nitrate the behave well because they have values higher than the recommended standards.

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INTRODUCTION

Human practices such as grazing, agriculture, land clearing, and space arrangements for housing purposes lead to accelerated erosion and deterioration of soil potential. As a result, soils fertility degradation is addressed by researchers from different scientific fields, such as soil science, geomorphology and forestry. Indeed, it is a significant environmental and agricultural threat (Asfaw and Nekan, 2017) that has developed across the world, affecting more than 20% of cultivated land, 30% of wooded areas and 10% of grasslands (Meliho *et al*., 2018). The soils fertility is characterized, among others by soils physico-chemical parameters degradation. Furthermore, the increase in pH at depth could be attributed to the leaching of fine particles from the surface to the deeper layers, leading to accumulation of nutrients as cations (Mg and K) and anions ($P_2O_4^-$, HCO_3^-, NO_3^-) in these horizons (Diallo *et al*., 2015).

This research explains the phenomenon of leaching and shows how this one leads to an accumulation of nutrients, changing the chemistry of deep soils. Moreover, the concentration of cations Ca^{2+}, Mg^{2+}, Na^+, and K^+ varied according to the carbon and nitrogen content, with Ca^{2+} as the most abundant cation, followed by Mg^{2+} and Na^+, while K^+ was the least abundant (Koné *et al*., 2014). Additionally, the assessment identified the use of poor land and inappropriate crop or soil management practices as major factors for soil fertility loss increase (Labrière *et al*., 2015). In humid tropical areas, soils fertility degradation may have several reasons including water erosion of the soil. Many studies of land degradation at worldwide scale claim Africa is particularly vulnerable to soil fertility loss and arguably the most severely affected region (Obalum *et al*., 2012). (Mohamed *et al*., 2022) investigated the assessment of soil fertility status under soil degradation rate using Geomatics in West Nile Delta.

Increasing deforestation and bad land use practices are leading to accelerated soil fertility degradation in the tropics areas(Victor *et al*, 2021).Soil degradation-induced decline in productivity of Sub-Saharan African soils assessment is performed in (Sunday *et al*., 2012). Lowland soil fertility degradation is addressed by several researches. (Nakao *et al*., 2021) addressed the changes in lowland paddy soil fertility in the Philippines after 50 years of the green revolution. (Emilio, 2019). Performed researches on Monitoring fertility degradation of agricultural Lands in the lowland tropics 1.Hillsides soils fertility degradation study is socio-economic factors matter for sustainable land use (Karna *et al*., 2020).Soil fertility degradation assessment in eroded hilly red soils of china is carried out by (Lu *et al*., 2004). Assessment of Soil degradation based on soil properties and spatial analysis in dryland farming is in (Kartini *et al*., 2023).

Research on the restoration of degraded soils has also been carried out by several researchers. Soil fertility in agricultural production units of tropical areas was investigated in (Torregroza-Espinosa *et al*., 2022). Restoring soil fertility on degraded lands to meet food, fuel, and climate security needs via perennialization study is carried out in (Mosier *et al*.,2021). (AbdelRahman *et al*., 2023) proposed an overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. (Rattan, 2015) carried out a research on restoring soil quality to mitigate soil degradation. Effects of compost and compost tea on soil Properties and nutrient uptake is studied in (Fatiha *et al*., 2024). (Valbon*et al*., 2019) studied challenges of soil resource protection in Sitnica River Basin (Kosovo). In the specific context of Guinea, and more particularly of the urban commune of N'zérékoré, the situation of soils degradation is very worrying. The Nakoyakpala district, located in this region, clearly illustrates the challenges posed by the degradation of hillside and lowland soils. Unfortunately, data on the state of deterioration of soil fertility in this area remains largely insufficient. This lack of complete and reliable data complicates the development of effective strategies to fight against erosion and loss of soil fertility. This paper, aims to fill this gap by providing a detailed assessment of the state of soil deterioration in the urban commune of N'zérékoré, taking the Nakoyakpala district as a case study. This paper is organized as follows. After the introduction section above, a description of the study zone is made. Then the Materials and Methods section is presented in which the experimental method and devises allowing computing physico-chemical parameters of soil are presented.

STUDY AREA

The Prefecture of N'zérékoré is one of the 33 prefectures of Guinea. It is the largest city in Forestry Guinea, a region in the southeast of the Republic of Guinea. The city is also the capital Forest region. It is located between 7°32 and 8°22 north latitude and 9°04 west longitude and extends over 47.3 km^2. The distance to neighboring prefectures is 39 km for N'Zérékoré-Lola, 62 km for N'Zérékoré-Yomou, 125 km for N'Zérékoré-Beyla, 135 km for N'Zérékoré-Macenta. Nzérékoré is at an elevation of 480 m and its relief is rugged.The plateau is dominated by hills that are sometimes gneissic (Gonia) and sometimes quartz (Gboyéba). The city has three important mountains: Götö (450 m), Hononye and Kwéléyé (350 m). Nakoyakpala is one of the 22 neighborhoods of the urban commune of N'zérékoré limited to the east by the rural commune of Bounouma, to the west by the Tilé river and the Mohomou district, to the south by the district of Kérémé, in North by the Gbangana district and the Tilé river.

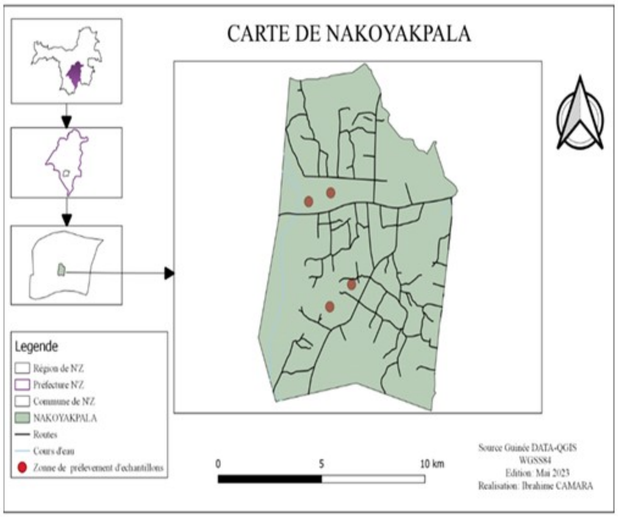

Figure 1. Map of the Nakoyakpala district

DATA AND METHIDS

Tools and materials: To carry out this research, we used certain materials and equipments to collect the data essential for determining soils physicochemical parameters. Table1 gives the materials and equipment and their function used in this study.

Table 1. Materials used and their functions

Materials	Function
The GPS	To find geographic coordinates
The shovels	For manipulate samples
The marker	To mark samples
Paper glue	To identify samples
A notepad	To write down the information
The centimeter	To measure the depth of sampling
The bucket	For mixing samples
The plastic	For samples transportation
The balance	To weigh samples
The beaker.	To measure the samples quantity
The plastic shovel	To take the samples and put them in the beaker
Graduated experiment	For measuring (samples and distilled water)
The spatula	To stir mixtures
Test tube	To mix samples
Glass pestle	To flatten the surface of samples
Sheets of paper	To spread the samples
The bottle agitator.	stir samples
The PF-3 photometer	For the determination of ammonium
The plastic funnel	To reduce the filter field
Filter paper	For solution filtration
The wash bottle	To rinse the equipment
The sieve	To sieve samples
The test strip	For reading pH, Nitrite and Nitrate
The syringe.	To collect the solutions

The following reagents were used.
Pyrophosphate
Calcium chloride Cacl2
$NH_4^{-}1$
NH_4^{-2}
NH_4^{-3}

Data analysis

Sampling procedure: To collect the information, we carried out a survey through the survey sheets designed on the Kobotoolbox platform (KOBOCOLLECT). For soil samples collection, we used a random method that consists of dividing the land into imaginary squares, and a sample was taken from each corner and the middle. Then all the samples taken were mixed to obtain a homogeneous mixture of all the soils of the land. Four land were sampled, including (2) on the lowland and two (2) on the hillsides

Soils type identification: A soil sample is crushed by hand in the sieve and separated from foreign particles. The sifted Sample is poured into the test tube and lightly tamped using a glass pestle. The sample level should reach the E mark on the tube. If necessary, the test tube should be struck several times in the palm of the hand to settle its contents. It must then be filled with water up to the F mark under the lid. Ten (10) drops of pyrophosphate must be added to prevent flocculation of clay particles. The test tube is then closed and shaken vigorously until to obtain a homogeneous mixture of water and soil. For heavily loamy soils, the samples are first soaked and then shaken vigorously. The shaking will then be stopped suddenly and the test tube will be vertically oriented. After 18 seconds, the sand particles settled, the height of the sand fraction reached one of the four lower marks after these 18 seconds. We read the corresponding letter and can deduce the soil type from the Table 2 below.

Table 2. Soils type identification

1. Mark	2. Sand %	3. Soils type
E	100-91	Sable
D	90-87	Slightly loamy Sand
C	86-82	Loamy Sand
	81-77	Very loamy sand
B	76-71	Sandy loam
	70-54	Limon
A	55-40	Heavy Silt
	40-0	Clay

Soils Physicochemical parameters determining

Humidity: To determine the humidity, we weigh 200g of the sample and spread it evenly on A4 paper, crush any large clumps and leave to dry for 16 to 24 hours in a well-ventilated room. After drying, return the sample to the beaker used to zero the balance. Record the weight. Humidity is now computed by the following relation

$$\text{Humidity (\%)} = \frac{\text{soaked weight (g)} - \text{dry weigth (g)}}{\text{soaked weight (g)}} \text{ X } 100$$

Nitrite/Nitrate Concentration: To measure the nitrite/nitrate concentration in the soil type A, the Quantofixnitrate/nitrite test tabs are used. A tab is briefly immersed (approximately 1s) in the soil type A. After 60s, the measuring area of the tab is compared with the colored scale. In the presence of nitrate ion, the measuring area at the end of the tab turns red-purple. The second reactive zone on the tab shows the nitrite concentration.

pH Measurement: The pH and ammonium are determined through the AF soil type (table-1). 100g of the sample is measured in an agitator bottle to which 200ml of soil extract is added. The mixture is then stirred vigorously for 5 minutes and then poured into a graduated experiment by filtering through a plastic funnel and filter paper. To measure the pH, we rinse the test tube with distilled water and add 10 ml of the filtered solution through a plastic syringe, then immerse the strip in it for 5 minutes and proceed to reading.

RESULTS AND DISCUSSION

The results presented are of two types. : a) The results of the survey on the factors leading to soil fertility degradation and b) the results of soils analyses showing the degradation of soils physicochemical parameters. These parameters will be compared to standard norms to highlight the soil fertility degradation.

Results of the survey on the factors leading to the soil fertility degradation: We first show the results of the survey concerning the methods of agriculture practiced in Nakoyakpala district (Figure 2). The results show that more farmers in the Nakoyakpala district practice seasonal crops than perennial crops.

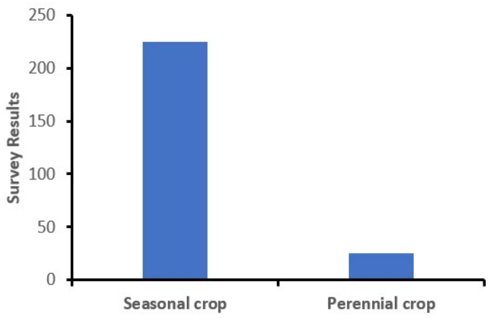

Figure 2. Type of crop practiced in the Nakoyakpala district

Secondly we present the results of the survey concerning the impact of runoff water on the soil (Figure 3).

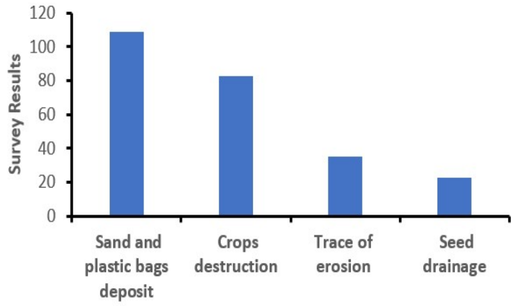

Figure 3. Impact of runoff water in Nakoyakpala district soils

These impacts are characterized by deposits of sand and plastic bags which contribute to the reduction of soil fertility on the lowlands and hillsides. According to the same surveys, 60% of farmers use chemical inputs and 40% the organic inputs (Figure 4). The impacts of use of these chemical and organics inputs are among others: soil compaction, disappearance of micro-organisms which contribute to soil fertility.

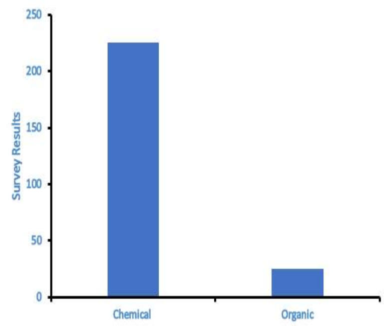

Figure 4. Use of chemical and organic inputs in Nakoyakpala district soils

From the survey, we also represent the methods of ploughing practiced in Nakoyakpala district (Figure 5). It reveals that parallel ploughing is dominant and this exposes the soil to erosion and leads to soil degradation.

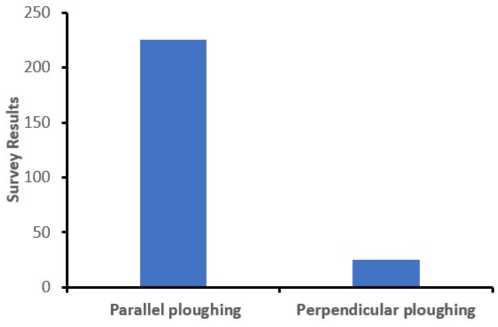

Figure 5. Ploughing practiced in Nakoyakpala district

Another element explaining the loss of soil fertility revealed by the survey is waste management. The results of the survey show that most of the population of the Nakoyakpala district dumps their waste into the ditches (Figure 6), which are directly drained into the lowland.

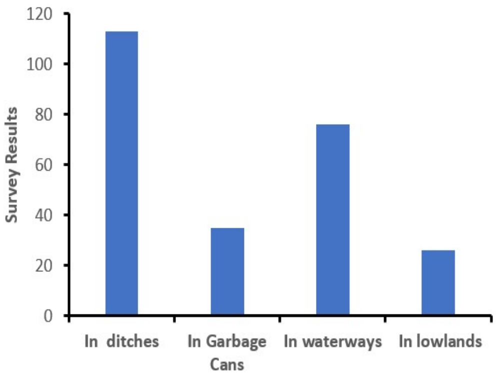

Figure 6. Waste disposal locations in Nakoyakpala district

A final explanation element of the loss of soil fertility is the frequency of soils use. In response to the questions asked, the survey indicates that the majority of the neighborhood's Nakoyakpala district don't leave soils resting (Figure 7). This is expected to lead to harmful effects on the soil such as the depletion of soils nutrients

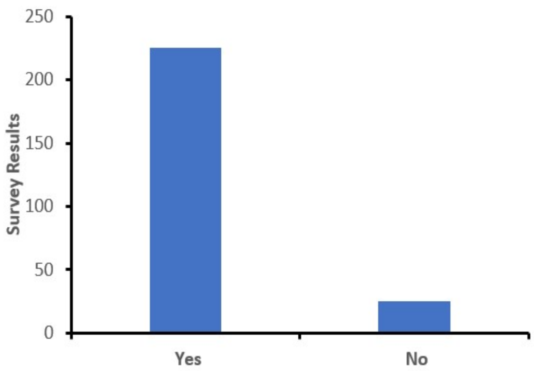

Figure 7. Answer to the question do you have the soils rest

Results of soils analyses showing the physico-chemical parameters degradation: In this subsection, we present the results of physico-chemical parameters analysis for two lowland soils and two hillside soils.

The results will be compare to the recommended standards values for the same fertile soils. Figure 8-9, show the physicochemical parameters for lowland soils 1 and 2.

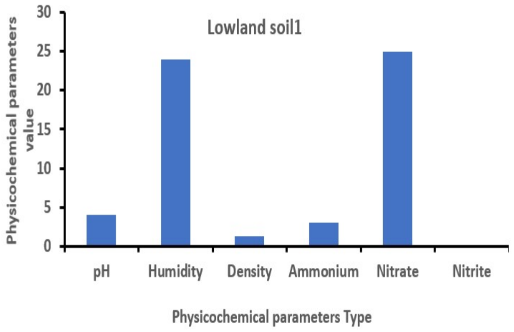

Figure 8. Physico-chemical parameters for lowland soils 1

From the results of the laboratory analysis (Figure 8), we find that the soil in Lowland1 is acidic, the humidity, nitrate concentration are high, the density and ammonium concentration are low, and there is no presence of nitrite.

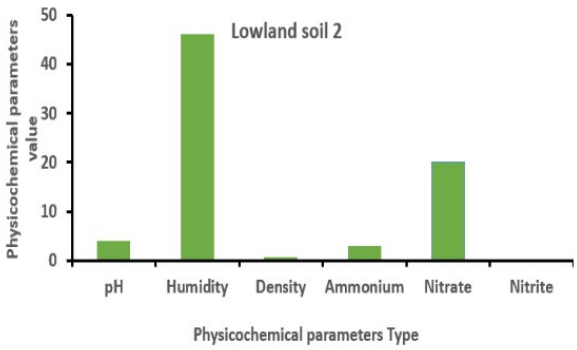

Figure 9. Physico-chemical parameters for lowland soils 2

According to the results of the analyses, we can see that the second lowland (Figure 9) has the same characteristics as lowland soils 1, except that its density is a little low. Figure (10-11), show the physicochemical parameters for hillside soils 1 and 2.

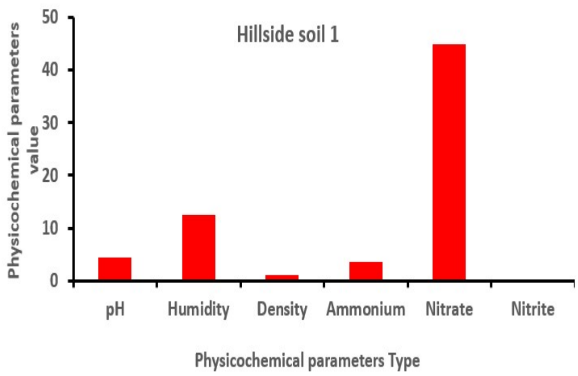

Figure 10. Physico-chemical parameters for hillside soils1

For hillside 1 (Figure 10), the soil is acidic, the humidity is average, the ammonium concentration and density are low. In hillside 2, the humidity and nitrate concentration are high while the soil is acidic, the density is low but the ammonium concentration is average. Finally we present a comparison of different soils.

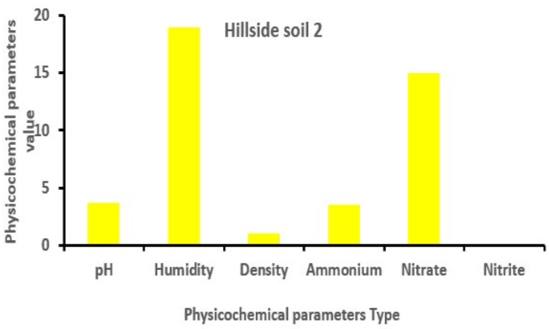

Figure11. Physico-chemical parameters for hillside soils 2

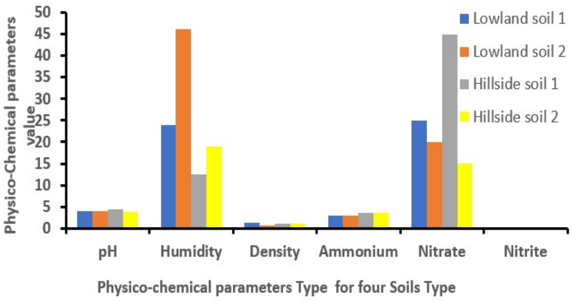

Figure 12. Physico-chemical parameters for the four soils type

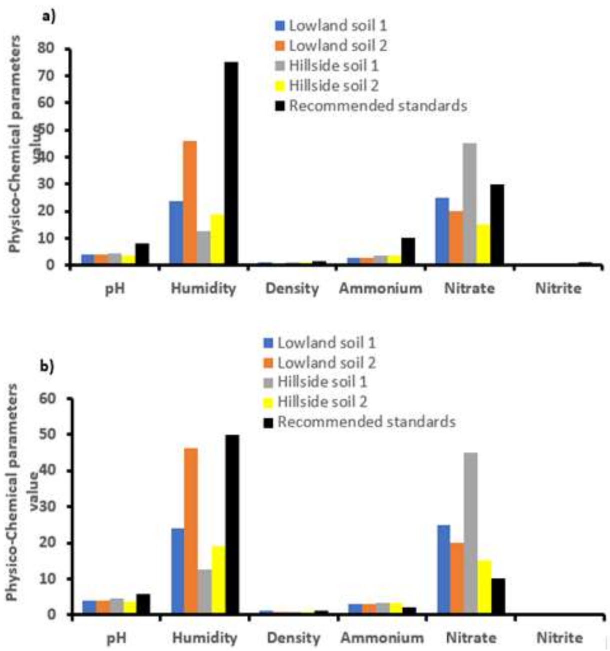

Figure 13. Comparison between

Table 3. Recommended Standards value of Lowland and Hillside soil physicochemical parameters

Parameter	value
pH	5.8 - 7.0
Humidity (%)	50 - 75
Density (g/cm^3)	1.1 - 1.4
Ammonium (NH4+) (mg/l)	2-10
Nitrate (NO3-) (mg/l)	10-30
Nitrite (NO2-) (mg/l)	< 1

Figure 12 the physicochemical parameters of the four soils analyzed. To highlight the soil fertility degradation in Nakoyakpala district we compare the physicochemical parameters of its lowland and Hillside soils analyzed to the same parameters recommended standadrs for fertile lowland and hillside soils. Table 3 (22FAO, 2006;FAO, 1998; FIDA, 2010) gives the recommended standards values of physico-chemical parameters of fertile lowland and Hillside soils. Figure 13 illustrates the comparison between Nakoyakpala district soils physicochemical parameters and those recommended for same fertile soils. The comparison concerned the maximum and minimum values of the recommended standards (Figure 13 a-b). For both Figures it is clearly shown the following parameters pH, Humidity, density and ammonium of Nakoyakpala district soils are well below the recommended standards. However in nitrate content they behave well because they have values higher than the recommended standards, thus illustrating the degradation of their fertility.

CONCLUSION

This paper allowed to investigate Nakoyakpala district lowland and Hillside soil fertility degradation. To achieve this objective, systematic random survey on the factors leading to the soil fertility degradation and physicochemical parameters analysis of soil using photometry were used. The results showed that 65% of farmers practice parallel crop, 60% of them use chemical inputs and 80% dump waste into ditches, lowlands and waterways. Thus the lowland soils are more humid with a rate of 46.1%, the nitrate content (NO3-) in the lowlands varies between 25mg/l and 20mg/l, while on the hillsides is between 15mg/l and 45mg/l. Ammonium (NH4+) is higher in the hillsides with 3.5 mg/l than the lowlands with 3 mg/l. The pH varies between 4 and 4.5.To illustrate the soil fertility degradation, physicochemical parameters of Nakoyakpala district lowland and Hillside soils were compared to the same parameters recommended standadrs for fertile lowland and hillside soils. The results indicated the following parameters pH, Humidity, density and ammonium of Nakoyakpala district soils are well below the recommended standards. However in nitrate content they behave well because they have values higher than the recommended standards, thus illustrating the degradation of their fertility.

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